THE EFFECTS OF VARIABLE SITE OCCUPATION SPAN ON THE RESULTS OF FREQUENCY SERIATION

Philip L. F. de Barros

It is argued here that the effects of variable site occupation span on frequency seriation have not yet been clearly elucidated. The necessary clarification is provided by graphic models used to generate simulated data which are then seriated. After an analysis of the seriation results, it is concluded that site duration variability poses a more serious problem for frequency seriations than was once thought. Possible solutions are then discussed. It is shown that no solution is in the offing for typological seriations, although it is possible to estimate the magnitude of the errors produced. Something approaching a solution does exist, however, for attribute microseriations.

AS MANY AUTHORS have pointed out (Rowe 1961; Johnson 1972:310–311), seriation is basically a technique which orders or scales units according to their similarities; however, because the multiple temporal, spatial, and cultural factors affecting the similarities are not known, the results of a given seriation may or may not be an accurate chronology (Cowgill 1968b; Dunnell 1970; Read 1974b). As Read (1974b:4) has stated, "the assumption that cultural ordering reflects chronological ordering" frequently remains unverified.

Attempts to resolve this dilemma are of four basic kinds: (1) the search for good data, i.e., data that produce a temporal ordering when scaled by whatever technique (see Ford in Phillips et al. [1951:219–236]; Ford [1962]; Rouse [1967]; Dunnell [1970, 1971:163–164]; McNutt [1973]; Marquardt [1974, 1979]; LeBlanc [1975]; (2) the use of multivariate statistical techniques to produce a linear ordering based on the temporal dimension in the data (Cowgill 1968a; Marquardt 1974, 1979; LeBlanc 1975; Drennan 1976; Matson and Lipe 1977); (3) the seriation of site clusters (derived from a cluster analysis) as opposed to the seriation of individual sites (Read 1974a, 1979; Plog 1976; see also Matson and Lipe [1977:9–26]); and (4) the use of independent data to confirm that a basically temporal ordering has in fact been produced (Meighan 1959; Rowe 1961; Hole and Shaw 1967:51–59; Johnson and Johnson 1975; LeBlanc 1975; South 1978; Read 1979). This paper deals with an aspect of the first approach.

There are many factors that affect the quality of the data upon which seriations are based. Those associated with the seriation of ceramic data have been chosen for this paper because ceramic-based seriation is probably the most common in the literature, and because these factors also apply to the seriation of other artifacts or collections of artifacts (Rouse 1967). These include spatial variability (see Ford in Phillips et al. 1951:223; Deetz and Dethlefsen 1965; Rouse 1967; Dunnell 1970; Read 1979), functional variability (McNutt 1973), sampling and measurement error (Cowgill 1970; Fish 1978), differences in ceramic tradition (see Ford in Phillips et al. [1951:223]; Rowe [1961]; Rouse [1967]; Dunnell [1970]), inadequate definition of ceramic types or attributes (Ford 1962:27; Cowgill 1968b; Dunnell 1971:139), and variability in site occupation length (Rouse 1967; Dunnell 1970; Cowgill 1972:384–385; David 1972; DeBoer 1974).

Most of these issues have been investigated with considerable clarity, such as Deetz and Dethlefsen's (1965) and Dunnell's (1970) discussions of spatial variability and McNutt's (1973) discussion of the importance of seriating ceramic types associated with vessels of the same functional

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class. These articles clearly explain and demonstrate the nature of these problems and then discuss how the archaeologist might deal with them. *But the nature of the effects of variable site occupation span upon seriation results has not benefited from such an analysis.* It is my intention to provide such clarification and to discuss the implications for seriation as a chronological tool. As the reader will soon see, variable site occupation span is a more important source of error than previously thought.

SERIATION AND SITE DURATION VARIABILITY: DEFINITION OF THE PROBLEM

The problem, basically, is this: variation in site occupation span may, if ignored, distort a seriated order so that it fails to represent a correct chronology. Thus, even if errors due to sampling, spatial variability, mixed ceramic traditions, and so forth, are avoided, variability in site occupation span alone is sufficient to produce errors in site chronology.

Variable Occupation Span in the Literature

The question of site duration was first mentioned by Ford (Phillips et al. 1951:219–220, 231–232) who felt that all units to be seriated (whether they be excavation units or surface collections) should be of short duration. Both he, and later Dunnell (1970), have emphasized that this permits the development of more refined chronologies. Rouse (1967) was the first to point out, however, that it is more important that sites be of *comparable* duration. Dunnell (1970) agrees, and is the first to propose a solution. He correctly states that it is generally not possible (except in the most obvious cases) to establish whether sites are of comparable duration, and that, therefore, a more useful approach is to attack the problem from the point of view of results. He maintains that important variations in site duration will either create a set of data that will not seriate or will generate a few sites that are noticeably out of line when Ford's graphic seriation method is used (Dunnell 1970:312, Figure 3; see Figure 1 of this paper). His solution is to remove any units which do not fit the unimodal curve assumption, except for those which result in minor fluctuations about the ends of pottery type temporal distributions (Dunnell 1970:313). This solution assumes that any important deviation from the unimodal curve model is due to site duration variability. In fact, it may be due to some other source, such as sampling error or spatial variability (Marquardt 1978:297–298).

Cowgill (1972:384–385) does not deal with the problem directly but asserts that seriations involving sites whose occupation spans *overlap* to any serious degree will tend to produce reversals in site order, whether in the presence of variable site occupation span or other sources of error, such as sampling error.

David (1972) and DeBoer (1974) show that the interaction between differences in ceramic vessel longevity and differences in site occupation span may produce artifact frequencies in archaeological middens which do not accurately reflect the frequencies of artifacts in use when the site was occupied. Schiffer (1975b) amplifies this point by including the effects of curation behavior (Binford 1973) on artifact frequencies. Finally, both David (1972:141–142) and DeBoer (1974:337) note that differences in pot life span and site occupation length may interact to create erroneous seriation results.

In short:

1. *Almost everyone* agrees that variability in site occupation span can affect seriation results in a negative way.
2. *Almost no one*, other than perhaps David, has shown precisely *how*, and *under what circumstances*, such variability affects seriation results. Is it always a problem, even with small differences in site duration? How serious are the distortions it may cause? Are there any other variables (in addition to artifact life span) that come into play?

As long as these questions remain unanswered, it is difficult to effectively evaluate Dunnell's and Cowgill's approaches to the problem or to suggest alternative solutions. To resolve this dilem-

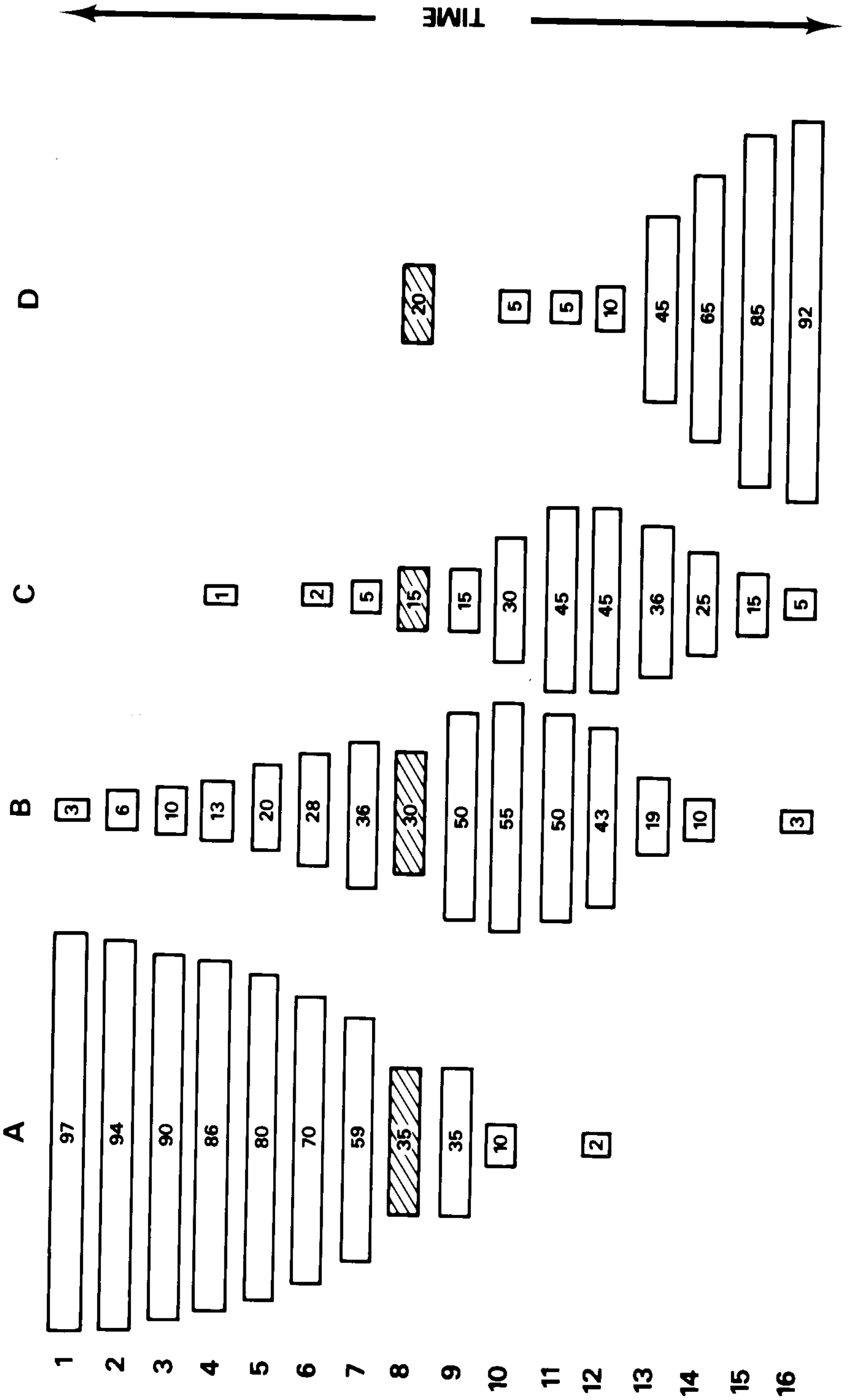

Figure 1. The effect upon the seriation pattern of one site not of comparable duration with the remainder of the sites. A–D are the pottery types, 1–16 are the sites. Site 8 is the noncomparable one (after Dunnell [1970:Figure 3]).

ma I have approached the problem by seriating sets of simulated data generated from a set of graphic models involving sites of variable occupation span (an idea suggested to me by Dwight Read). As is shown below, these models will permit us to isolate and examine the effects of site duration variability under varying sets of conditions. Then, in the light of such knowledge, the validity of Dunnell's and Cowgill's approaches will be reexamined and other possible solutions to the problem will be discussed. As for the interaction between variable pot life span and variable site occupation span, its effects can be assessed without the use of seriations of simulated data, and it will be shown that in most practical situations such interaction has little or no negative effect upon seriation results.

THE USE OF GRAPHIC MODELS TO ELICIT THE EFFECTS OF VARIABLE OCCUPATION SPAN UPON SERIATION

Before elaborating on the graphic models, it should be noted that this study deals with the effects of variable site occupation span upon a *frequency* seriation (which uses artifact frequency data) as opposed to an occurrence seriation (which uses presence-absence data) (see Rouse [1967] and Dunnell [1970]). This, in turn, entails the assumption that when sites are seriated, one is attempting to arrange site *median* occupation dates in chronological order (see Ford in Phillips et al. [1951:234–235]; Dunnell [1970]; and South [1978]).

Frequency seriation was chosen for this study because it permits the development of more refined chronologies, and because such chronologies are increasingly in demand by archaeologists interested in processual and systemic analysis (LeBlanc 1975). This is not to say that occurrence seriation is of no value. As LeBlanc (1975) points out, it is particularly useful for certain kinds of archaeological data, such as those provided by grave lots (see Cowgill [1972]). Although I suspect that the effects of variable occupation span upon occurrence seriations are relatively less important, a separate study would be needed to determine this.

The General Form of the Graphic Models

The general form of the models can best be described as a set of unimodal production curves for a succession of pottery types set within a Cartesian coordinate system (see Figure 2; see also Schiffer [1975a:Figure 2]). A basic assumption of frequency seriation is that most pottery (or other artifact) types exhibit a unimodal curve of production over time. This assumption goes back to Kroeber (1916) and Spier (1917) but was popularized by Ford (Phillips et al. 1951) who referred to a type's "popularity cycle" (Ford 1962). Types suspected of possessing a bimodal (or multimodal) distribution through time are to be excluded (Dunnell 1970).

The implication of the unimodal curve model is that as one type declines in production it is replaced by another. It is possible to represent this process in a Cartesian coordinate system, with the x-axis measured in units of relative time and the y-axis in arbitrary units of artifact frequency, e.g., 1, 10, 100, or some other fixed number of pots (see Figure 2). The model is thus relevant to a wide range of archaeological conditions.

Note, however, that the general model consists of production curves, whereas archaeological data are depositional in nature. Most authors have avoided this issue by treating popularity or production curves as deposition curves (Ford 1962; Rouse 1967; Dunnell 1970; LeBlanc 1975; for an exception, see Schiffer [1975b]), though none of them justify this procedure. However, if one is willing to ignore the occasional occurrence of an heirloom pot, then treating a production curve as a deposition curve is a reasonable step. A pottery type's deposition curve is essentially identical to its curve of production, except that the former occurs slightly later in time (the displacement being equal to the average uselife of the pots produced; see Schiffer [1976:61–65]). Since this temporal shift does not affect the relative frequencies of the pottery types, seriation results will not be affected.

With the kind of graphic model used here, the relative frequency in percent of each pottery type deposited in the archaeological record during a given set of relative time units (i.e., for a given site

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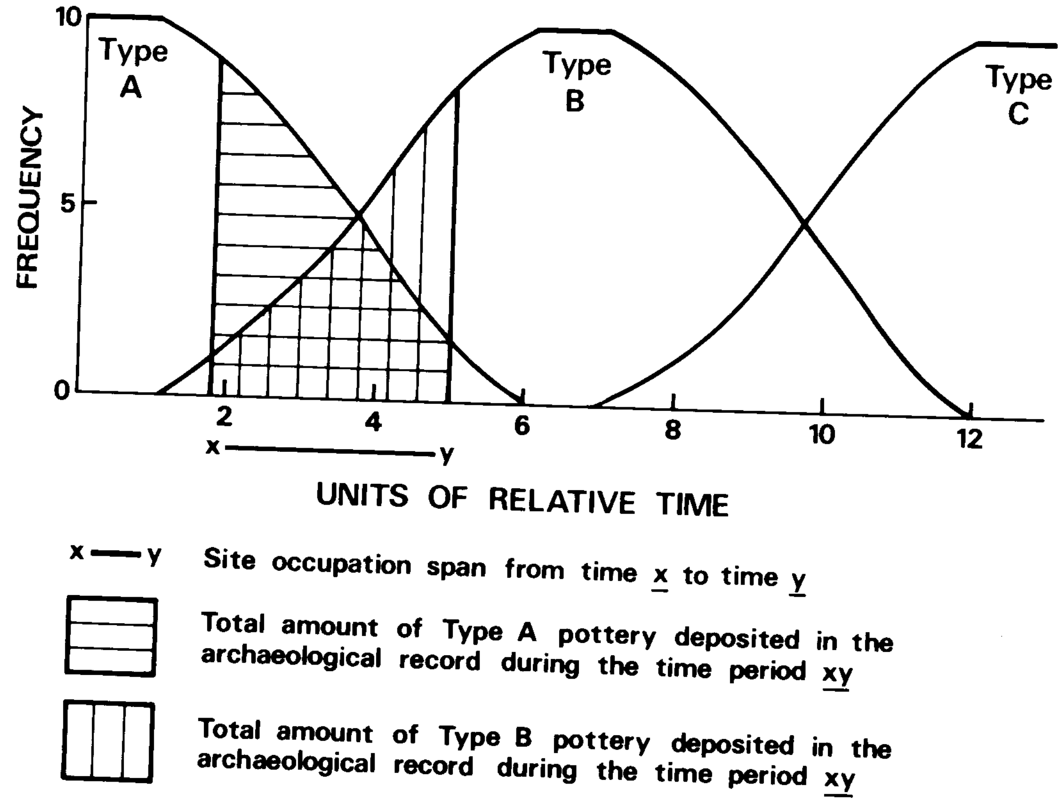

Figure 2. Types A–C represent an example of a succession of unimodal pottery type production curves set within a Cartesian coordinate system.

The relative frequency of Type A pottery deposited in the archaeological record during the time period *xy* is obtained by dividing the amount of Type A (area under the production curve for Type A) by the total amount of Types A and B deposited during the same time period.

occupation span) can be derived from the calculation of the areas under the appropriate sections of the model's production curves (see Figure 2). By repeating this procedure for a set of sites of variable occupation span, one can generate simulated data for analysis. By varying both the form of the production curves (by varying the model) and the relative degree of site duration variability (by making the sites of longer duration increasingly larger multiples of the sites of short duration), different sets of simulated data can be generated. These can then be seriated to test for the effects of variable occupation span under the conditions specific to each model.

The Specific Forms of the Graphic Models

The streamlined unimodal curve models illustrated and explained in Figures 3–11 were designed to test for the effects of site duration variability within the following contexts:

1. changes in the length of the period of maximum production of a given pottery type (see Models 1, 2, and 3A);
2. changes in the rate at which one ceramic type replaces another (see Models 3A, 3B, and 3C);
3. changes in the number of contemporaneously produced pottery types (see Model 4);
4. a leveling off in production during a type's rise or decline (see Models 5A and 5B which have leveling-off periods of different length); and
5. small-scale reversals in the production of a type (see Model 6).

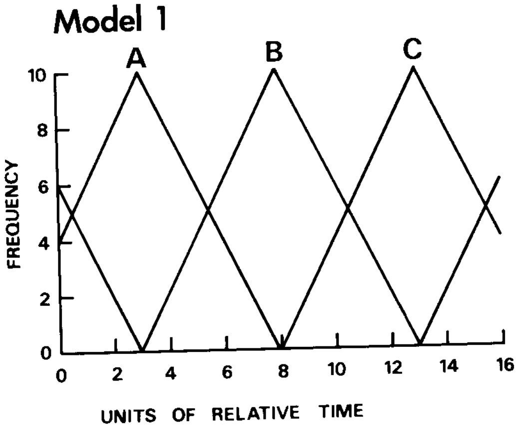

Figure 3. *Model 1.* **The unimodal curves represent a succession of pottery types whose period of maximum production is only momentary. The slope of the curves—a measure of the rate of pottery type replacement—is |2|, a relatively moderate slope.**

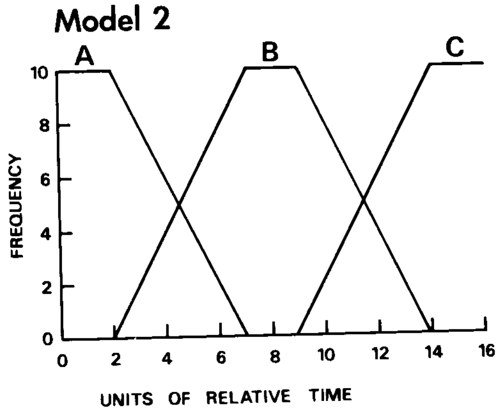

Figure 4. *Model 2.* **The unimodal curves represent pottery types that maintain their level of maximum production for two units of relative time. The slope of the curves remains at |2|.**

In addition, by varying the interval between site median occupation dates, or by increasing or decreasing the occupation lengths of all sites in the production of simulated data for a given model, or both, one can observe what happens when there are:

6. changes in the interval between site median occupation dates (this will be done with Models 3A and 5A);

7. changes in the occupation lengths of all sites relative to the overall life span of a given pottery type (this will be done with Model 3A); and

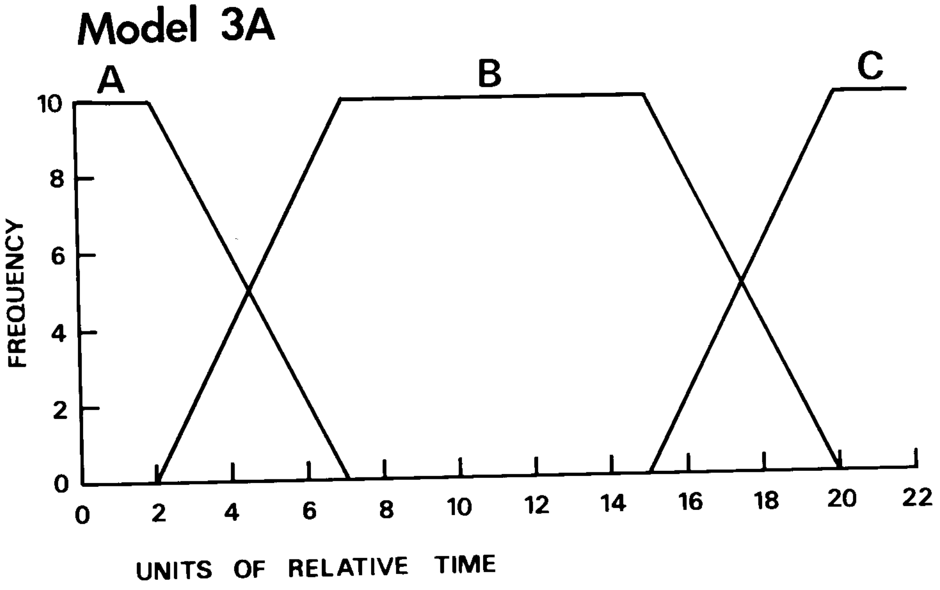

Figure 5. *Model 3A.* **The period of maximum production lasts for eight relative time units. The slope remains moderate, i.e., |2|.**

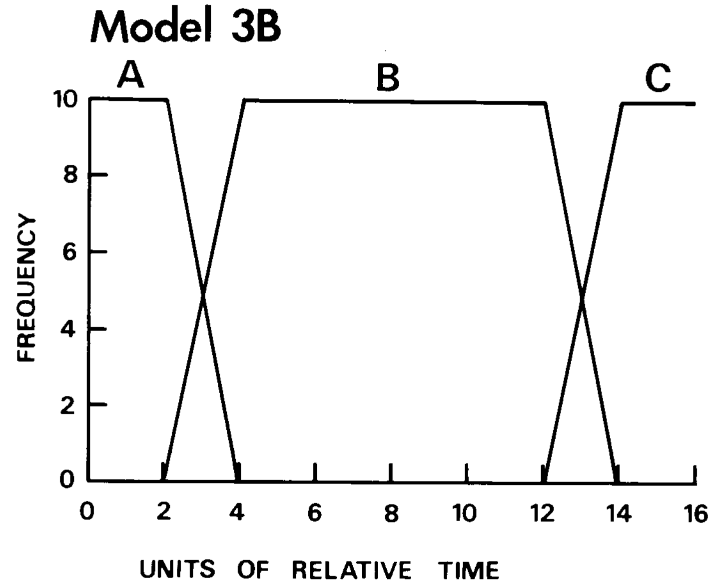

Figure 6. *Model 3B.* **Model 3B is identical to Model 3A, except its slope is |5|, a relatively steep slope.**

8. changes in both interval and length (this will be done with Models 3A, 5A, 5B, and 6).

Finally, it is worth discussing whether or not the models represent typical pottery type production curves. Tree-ring dated pottery sequences from the American Southwest (Breternitz 1966; see also Colton [1953:75, 78]; Stubbs and Stallings [1953:Figure 70]) and the known dates of manufacture for English ceramics of the American colonial period (South 1972:Figure 1) suggest that Models 2, 3A, 3B, and 4 are very common, whereas Model 3C is probably rare. In particular, these sequences suggest that the transition period between zones of maximum production for two temporally adjacent types is relatively rapid. However, this evidence deals mainly with painted types, and cases of Model 3C may occur among unpainted, utility ware sequences where ceramic change is generally much slower (see Mera [1935:genealogical chart in appendix]). In fact, it should be pointed out that pottery type life spans are sometimes the result of the archaeologist's arbitrarily dividing up a continuum of ceramic change. If one were to look at pottery from the perspective of ware life spans (as opposed to type life spans), Model 3C may be relatively common. As for Models 1, 5, and 6, their existence seems plausible, but there is no way to verify this. Nevertheless, these models are still useful because they allow one to see how site duration variability affects seriation for a wide range of possible cases.

It should be noted that the pottery type production curves in the graphic models may also be interpreted as sets of pottery attribute state production curves, and thus the results of this study will also be applicable to attribute frequency seriations (see the concluding section below).

Assumptions of the Models and their Rationale

These graphic models for generating simulated data for seriations involve a simplification of archaeological reality and are based on the following assumptions:

1. that all pottery types have symmetrical, linear, unimodal production curves;

2. that the absolute dates and shapes of these curves do not vary from site to site, i.e., that spatial and functional variability of all kinds either do not exist or can be eliminated prior to seriation (a practical impossibility; see references cited above, third paragraph);

3. that pottery output for the set of types used in a given seriation is constant throughout the occupations of all sites (an unlikely occurrence); and

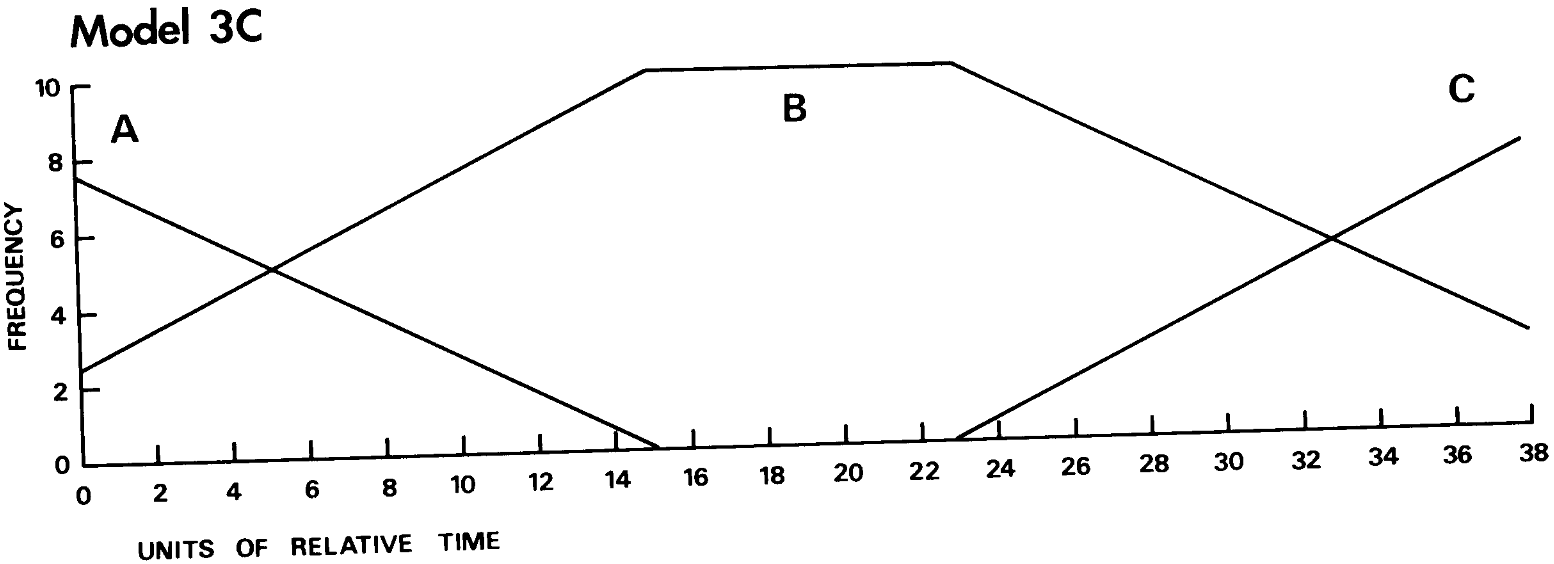

Figure 7. *Model 3C.* **Model 3C is identical to Model 3A, except its slope is |1/2|, a relatively gentle slope.**

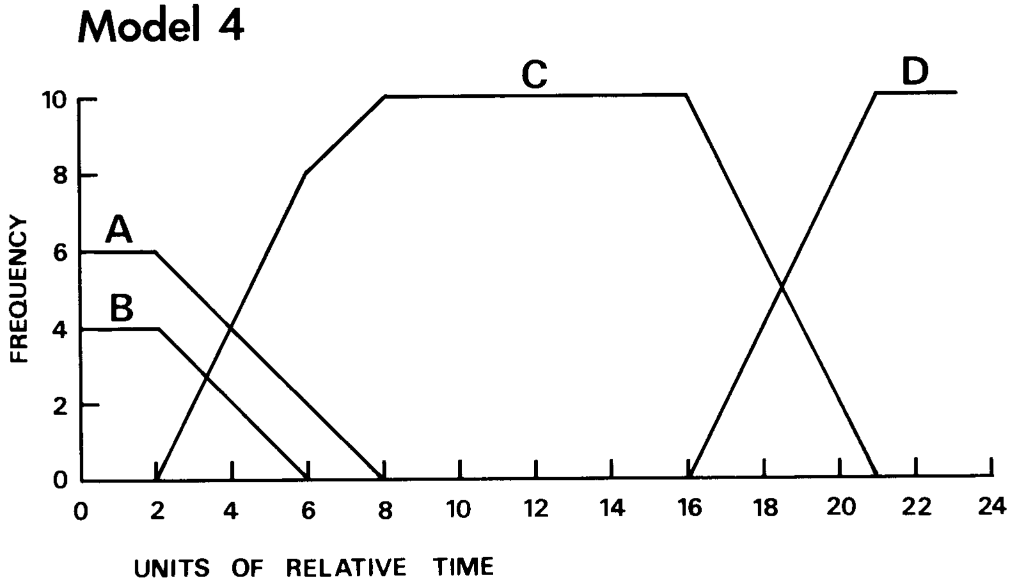

Figure 8. *Model 4.* **The effect of increasing the number of contemporaneously produced types is studied by comparing the number of errors (and error rates) on the two sides of Type C's production curve. Type C's curve is like those in Model 3A, except where the presence of a third type has decreased the slope from |2| to |1|.**

4. that the process of pottery deposition can be represented by a continuous function, $y = f(t)$, when it is in fact a discrete process.

In addition, it should be noted that in an actual seriation the archaeologist produces a chronology of pottery samples taken from a set of sites. From this chronology of samples, he must then infer a chronology of sites. This assumes that the samples accurately reflect the total ceramic assemblage used by the inhabitants of each site during its entire occupation span. Again, this is an unlikely occurrence (see Cowgill [1970], and Schiffer [1975b]).

The simplification of reality in the models can be justified in terms of this study's primary goal of determining the effects of site duration variability upon the results of frequency seriation. In effect, the models serve as *heuristic devices* to clarify the effects of variable site occupation span, *independent* of such factors as sampling error, spatiofunctional variability, and variable intrasite production rates. The use of models as heuristic devices is basic to scientific analysis, for it allows one to control events so that the effects of a particular variable (or set of variables) can be properly understood. If all of the complexity of seriation were to be contained in the graphic models, it would be impossible to elicit the specific effects of site duration variability.

The streamlined curves of the models are linear approximations to a unimodal curve. Note that in general such linear approximations do not radically change the original size, shape, or slope of such curves. The minor changes that do occur have a negligible effect on seriation results. Furthermore, the various forms of the models were designed to elicit the effects of such things as a leveling off in slope, differences in slope and small-scale reversals in production (see Figures 3-11). Finally, the streamlined models permit rapid and simple calculation of the areas beneath the curves from which are derived the relative frequencies of pottery types deposited at a site during a given time span (see Figure 2).

As for assumption four, the representation of the discrete process of pottery deposition by a continuous function permits one to use a generalized model of pottery production instead of repeating each set of simulations for a whole range of pottery production levels. Such a procedure is justified because the relative frequencies of pottery types produced by the continuous approxi-

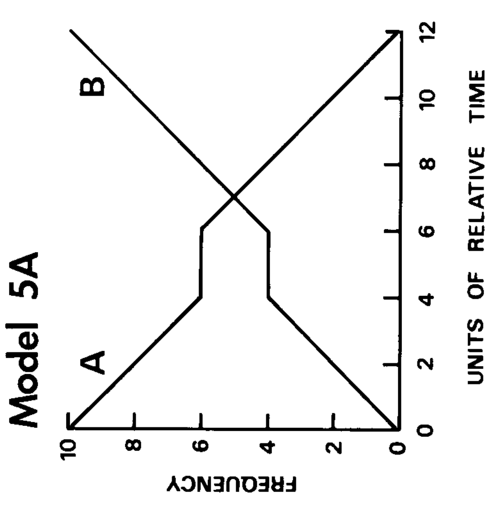

Figure 9. *Model 5A.* Model 5A was designed to study the effects of a leveling off in production during the rise or decline of a type. The leveling off period lasts for two units of relative time.

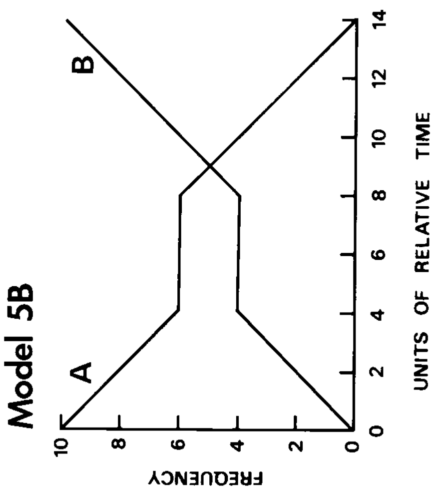

Figure 10. *Model 5B.* Model 5B is identical to Model 5A, except the leveling off period lasts for four units of relative time.

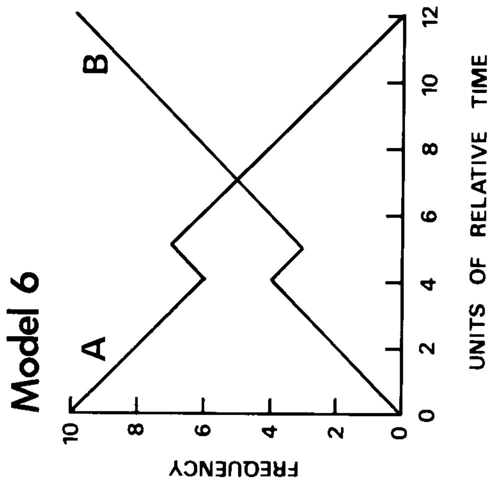

Figure 11. *Model 6.* Model 6 was designed to test for the effects of a small-scale reversal in production during the rise or decline of a type.

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mation are not significantly different from those produced by the discrete approach except at low levels of production (e.g., 10 pots/decade), thus rendering the models applicable to most archaeological situations.

PROCEDURES USED FOR DATA GENERATION AND SERIATION

Generation of the Simulated Data

For all seriations, sites of relatively short duration (equal to one to four units of relative time) were seriated with sets of sites that were multiples of these shorter units. For example, for all models, a set of sites of occupation length *t* was seriated with sets of sites of length *2t*, *3t*, on up to *6t*, or to whatever point seemed informative. (Henceforth, the short units shall be called *basal units*, and their multiples shall be called *longer units*.)

Except for those seriations testing for the effects of varying the interval between site median occupation dates, basal units were placed adjacent to each other across the portion of the central production curve that represents its period of dominance as a type. These were then seriated with all longer units whose median occupation dates fell exactly midway between the medians of two adjacent basal units (see Figure 12). Note, however, that any unit whose entire occupation span fell entirely within the production period of a single type was not included in the seriation, as would be true in a real seriation (see Figure 12).

To obtain a good estimate of the range of errors that variable occupation span may generate, each combination of basal and longer units for each model was seriated twice (whenever possible). In the first seriation run, Run A, the basal units were placed so that the junctures between different rates of ceramic change would coincide with the median occupation dates of the longer units. For the second run, Run B, these junctures coincided with the basal unit median occupation dates (see Figure 12 and Table 1).

Seriation of the Data

The seriation procedure involves a simplified version of the Ford graphic method (Ford 1962) used in conjunction with the Renfrew–Sterud Double-Link method (Renfrew and Sterud 1969). After the generation of the frequency data for a given seriation, the first step was to arrange the basal units in chronological order on a sheet of paper (leaving space for the insertion of the longer units). If all longer units could then be inserted so as to provide an unambiguous solution (except for ties) that did not violate the assumptions of the unimodal curve model (i.e., no reversals or discontinuities in pottery type distributions; see Dunnell [1970]), the error rate could then be determined from this graphic solution (see the next section). If such a solution was not possible, then the Renfrew–Sterud Double-Link method was used. (This second step turned out to be necessary only for the data generated from Models 1, 2, 3A, and 4.)

A few comments about the methods chosen are in order:

1. A multidimensional seriation technique was judged unnecessary because the models were designed to eliminate nontemporal variability, whether it be functional, spatial, or otherwise.

2. The simplified version of the Ford graphic method not only saves time without affecting the validity of the results of this study, it also permits the isolation of errors due to variable occupation span from errors which would occur without it (e.g., for Models 5A, 5B, and 6, a leveling off or a small-scale reversal in production can produce seriation errors even with sites of equal occupation span). In addition, the use of the graphic method also provides important insights into the validity of Dunnell's proposed solution (see below; see also Dunnell's [1970] use of the Ford graphic method).

3. The Renfrew–Sterud Double-Link method was chosen over other formal seriation techniques because it is rapid and because it gives results equivalent to more sophisticated methods, such as Gelfand's Method II (Gelfand 1971). Furthermore, the Renfrew–Sterud approach reacts very nicely to serious distortion by refusing to seriate, i.e., side chains occur (see Figure 13), and no single

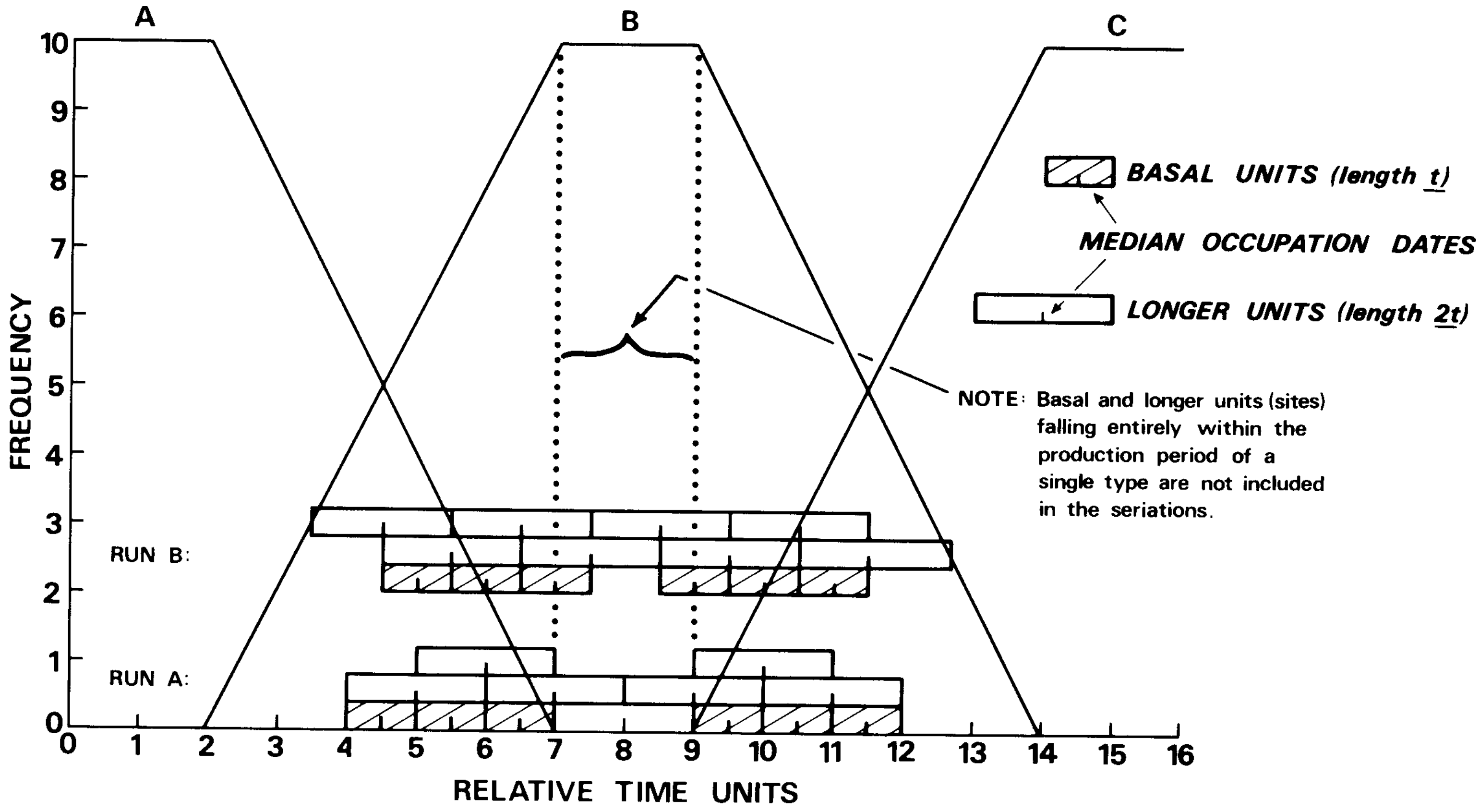

Figure 12. Graphical display of the procedure for generating simulated data for seriation. Runs A and B are made to obtain a good estimate of the potential error range. (Units outside the central curve's period of dominance are not included because they would simply provide redundant information; for Models 5A, 5B, and 6, however, no units were excluded.)

RELATIVE TIME UNITS

Figure 12. Graphical display of the procedure for generating simulated data for seriation. Runs A and B are made to obtain a good estimate of the potential error range. (Units outside the central curve's period of dominance are not included because they would simply provide redundant information; for Models 5A, 5B, and 6, however, no units were excluded.)

Table 1. Seriation Results.

Part I: Models 1, 2, 3A, 3B, 3C. BUs[a] length *t*, site median interval *t*/2.

MODEL 1

Mag. SDV[b]	Run[c]	Error Types[d]	No. of Errors	N[e]	Error Rate
2	A&B	—	0	10	0%
3	A	—	0	10	0%
	B	1SC(1)	—[f]	10	—
4	A	2SC(1)	—	10	—
	B	1SC(1)	—	10	—

MODEL 2

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	11/13	0%
3	A	—	0	12	0%
	B	2S	2	13	15%
4	A	2Ties	2	12	17%
	B	2S	2	13	15%
5	A	2S	2	12	17%
	B	2SC(1)	—	13	—

MODEL 3A

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	11/13	0%
3	A	—	0	13	0%
	B	2S	2	13	15%
4	A	2Ties	2	13	15%
	B	2S	2	15	13%
6	A	2S	2	15	13%
	B	2S, 2D	6	17	35%

MODEL 3B

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	5/7	0%
3	A	—	0	7	0%
	B	2S	2	7	29%
4	A	2Ties	2	7	29%
	B	2S	2	9	22%
6	A	2S	2	9	22%
	B	2D	4	11	36%

MODEL 3C

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	41/43	0%
3	A	—	0	43	0%
	B	2S	2	43	5%
4	A	2Ties	2	43	5%
	B	2S	2	45	4%
6	A	2S	2	45	4%
	B	2D	4	47	9%
8	A	2D	4	47	9%
	B	2S, 2T	8	49	16%

[a] BUs—basal units.

[b] Magnitude of site duration variability (longer unit multiples of BUs).

[c] Seriation run.

[d] S, D, T—single, double and triple displacement, respectively; SC(n)—side chain of *n* units.

[e] N—number units in seriation run.

[f] Side chains represent serious distortion; see text.

Part II: Model 3A using (1) BUs of 2*t*, SMI[g] of *t*; (2) BUs of 4*t*, SMI of 2*t*; (3) BUs of 2*t*, SMI of *t*/2; (4) BUs of 2*t*, SMI of 2*t*.

MODEL 3A(1)

Mag. SDV	Run	Error Types	No. of Error	N	Error Rate
2	A&B	—	0	6/8	0%
3	A	—	0	8	0%
	B	2S	2	8	25%
4	A	2Ties	2	8	25%
	B	2S	2	10	20%
6	A	2S	2	9	22%
	B	2D	4	10	40%

MODEL 3A(2)

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	3 1/2/5 1/2	0%
3	A	—	0	4 1/2	0%
	B	2S	2	5 1/2	36%
4	A	—	0	4 1/2	0%
	B	1SC(2)	—	5 1/2	—

MODEL 3A(3)

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	AB[h]	2S	2	15	13%
3	AB	4S	4	17	24%
4	AB	2S, 2D	6	19	32%
6	AB	2S, 2D, 2T	12	19	63%

MODEL 3A(4)

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	4/6	0%
3	A&B	—	0	4/6	0%
4	A	—	0	5	0%
	B	2Ties	2	6	33%
6	A	1S	1	5	20%
	B	2S	2	6	33%

[g] SMI—site median interval.

[h] Run A & B type units had to be combined into a single seriation.

(Table continues on the following page.)

Table 1. Continued.

Part III: Model 4 (Figure 8) compares the number of errors produced by two versus three contemporaneous types. BUs of length *t*, SMI of *t*/2.

MODEL 4: *Three Pottery Types*

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	8 1/2/9 1/2	0%
3	A	—	0	9 1/2	0%
	B	1S	1	9 1/2	11%
4	A	1Tie	1	9 1/2	11%
	B	1S	1	10 1/2	10%
6	A	2S	2	10 1/2	19%
	B	2S, 1D	4	11 1/2	35%

MODEL 4: *Two Pottery Types*

Mag. SDV	Run	Error Types	No. of Errors	N	Error Rate
2	A&B	—	0	5 1/2/6 1/2	0%
3	A	—	0	6 1/2	0%
	B	1S	1	6 1/2	15%
4	A	1Tie	1	6 1/2	15%
	B	1S	1	7 1/2	13%
6	A	1S	1	7 1/2	13%
	B	3S	3	8 1/2	35%

Part IV: Model 5A using (1) BUs of *t*, SMI of *t*/2; (2) BUs of 2*t*, SMI of *t*/2; (3) BUs of 2*t*, SMI of *t*; (4) BUs of 3*t*, SMI of 3*t*/2.

MODEL 5A(1)

Mag. SDV	Run	Error Types	No. of Errors
2	A&B	—	0
3	A	—	0
	B	2S	2
4	A	1Tie	1
	B	2S	2
6	A	1S	1
	B	2S, 2Ties	4

MODEL 5A(2)

Mag. SDV	Run	Error Types	No. of Errors
2	AB[i]	1Tie	1
3	AB	2Ties, 1S	3
4[j]	AB	3S	3

[i] Run A&B type units had to be combined into a single seriation.

[j] Further seriations impractical due to model's structure.

MODELS 5A(3) and 5A(4): No errors occurred up through site duration variability of magnitude eight.

Part V: Model 5B using (1) BUs of *t*, SMI of *t*/2; (2) BUs of 2*t*, SMI of *t*.

MODEL 5B(1)

Mag. SDV	Run	Error Types	No. of Errors
2	A&B	—	0
3	A	2S	2
	B	2S	2
4	A	2S, 1Tie	3
	B	4S	4
6	A	4S	4
	B	2S, 2D	6

MODEL 5B(2)

Mag. SDV	Run	Error Types	No. of Errors
2	A&B	—	0
3	A	—	0
	B	2S	2
4	A	2Ties	2
	B	2S	2
6	A	2S	2
	B	2S	2

Part VI: Model 6 using (1) BUs of *t*, SMI of *t*/2; (2) BUs of 2*t*, SMI of *t*.

MODEL 6(1)

Mag. SDV	Run	Error Types	No. of Errors
2	A&B	—	0
3	A&B	—	0
4	A	—	0
	B	2Ties	2
6	A	2Ties	2
	B	2S	2

MODEL 6(2)

Mag. SDV	Run	Error Types	No. of Errors
2	A&B	—	0
3	A&B	—	0
4	A&B	—	0
6	A&B	—	0

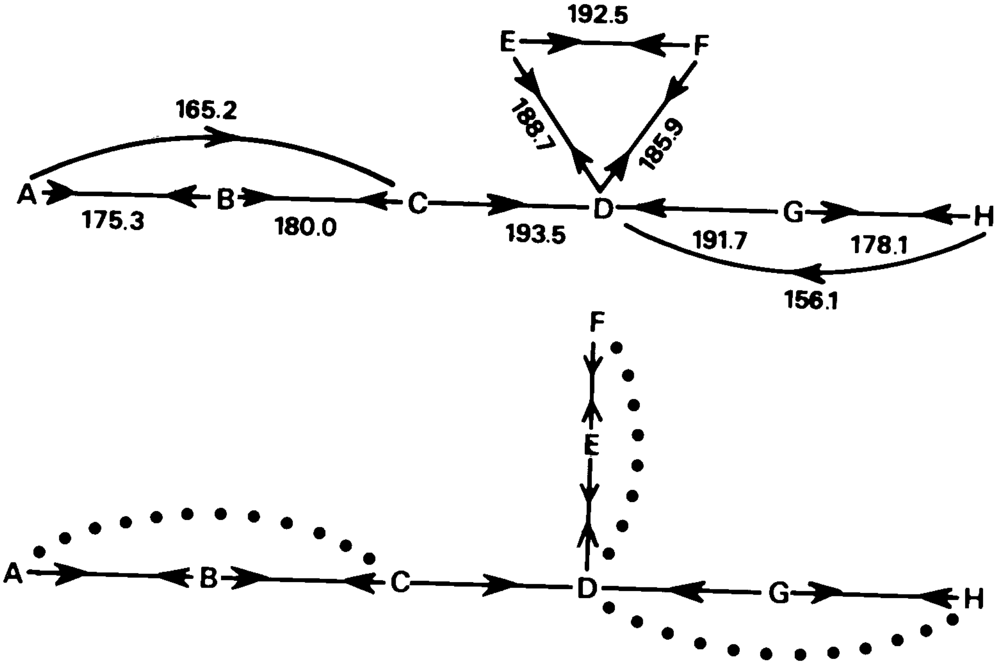

Figure 13. *The Renfrew-Sterud Double-Link method and the creation of side chains.* **After creating a Brainerd–Robinson similarity coefficient matrix, the following procedure is used for each site in turn:**

> **For each, the two most similar units, that is . . . the two which share the highest coefficients of similarity with the unit in question, are noted. These are placed on the paper beside the first and are linked to it by a bond marked with an arrow. This is repeated . . . until all units have been noted, each with two bonds, so that all are linked [see upper diagram]. . . . Any looping can then be broken by breaking the weakest bond in the loop [see lower diagram] [Renfrew and Sterud 1969:266].**

If it is linear, the resultant order is the seriated order. Sometimes, however, no linear order is possible and side chains occur, e.g., D-E-F.

linear order can be produced (Renfrew and Sterud 1969). This presence or absence of side chains serves as a useful interpretive device not available with other methods.

(Note: when the results of Gelfand's Methods I and II were compared with those obtained using the Renfrew-Sterud technique, there were few differences; moreover, what differences there were do not alter the underlying trends indicated in Table 1, nor do they alter the basic conclusions of this paper.)

Calculation of the Error Rate

The number of errors in a given seriation was obtained by determining the minimum number of positions necessary to displace a unit to achieve a correct order. For example, if A-B-C represents a seriated order, and the correct order is B-A-C, then by displacing B one position the correct order is achieved. One displacement of one position was counted as one error. Were it necessary to move A past C to obtain the correct order, this would be a displacement of two positions, or two errors. In this fashion more serious errors of placement were given correspondingly more weight.

The actual error rate for each seriation was calculated by dividing the number of errors by the total number of units (sites) seriated. If the Renfrew-Sterud technique produced side chains (see Figure 13), the units were considered unseriatable, and no error rate was calculated (e.g., see results for Model 1 below and in Table 1). If ties occurred, they were counted as one error for each pair of tied units. For Models 5A, 5B, and 6, units which could have been seriated incorrectly even if sites were of equal duration were excluded prior to calculating the error rate.

ANALYSIS OF SERIATION RESULTS

When reading Table 1, remember that except when no errors occurred, no claim is made that the error rates listed are the precise rates that would occur using real data. With real data, the actual temporal distributions of sites may or may not approximate the distributions used to generate the simulated data at each level of variable occupation span (see Figure 12); consequently, error rates may vary. Nevertheless, the error rates given in Table 1 are indicative of the general level of error and the error trends one can expect to encounter.

Seriation results will now be discussed within the contexts of variability specified by each of the models in turn.

1. *Changes in the Length of a Type's Period of Maximum Production*

Model 1. As stated earlier, the Renfrew-Sterud Double-Link method sometimes produces side chains. Its authors claim that this is a sign of nonlinearity in the data due to clustering or nontemporal variability (Renfrew and Sterud 1969:267, 271). In view of the results for Model 1 (Table 1), variable occupation span may also produce side chains. Moreover, if Gelfand's (1971) Method II is applied to the same data, the resultant order is so distorted that it is no longer meaningful to speak of an error rate. Seen in the context of a Ford graphic seriation, such distortions are due to the presence of units which create reversals within pottery type distributions (see Figure 1). If these units are removed, the error rate is dramatically reduced.

Model 2. Here, the serious distortion represented by the side chains does not occur until variable occupation span attains a magnitude of five; nevertheless, the error rate is still 15% at a magnitude of only three. In the context of a Ford graphic seriation, most of the errors are due to units which create discontinuities at the ends of distributions (see Figure 1).

Model 3A. The results are similar to those of Model 2 except that all incorrectly placed units would go *completely undetected* in a Ford graphic seriation (or any other seriation), because all units can be arranged so as to perfectly satisfy the assumptions of the unimodal curve model. In addition, if one were to increase Model 3A's period of maximum production to *20t*, or even *100t*, the error rates shown in Table 1 would remain the same and the unimodal curve model would not be violated.

In summary, it appears that if the length of the period of maximum production is brief, serious distortion may occur. More lengthy periods initially result in fewer errors, but a constant minimum level of error is quickly attained.

2. *Changes in the Rate of Pottery Type Replacement*

It is clear from Table 1 (see Part 1, Models 3B, 3A, and 3C) that the error rate is directly proportional to the rate at which one pottery type replaces another: Model 3B has the highest replacement rate and the highest error rate; Model 3A has a lower replacement rate and a correspondingly lower error rate; and, finally, Model 3C has the lowest replacement rate and the lowest error rate. Note that for relatively rapid type replacement, the error rate is 29% when the magnitude of variable occupation span is only three, whereas for relatively slow type replacement, the rate is still less than 10% even when the magnitude is six.

3. *Changes in the Number of Contemporaneously Produced Types*

The results for Model 4 are somewhat ambiguous (see Part III of Table 1). If the two halves of the central production curve are compared (see Figure 8), the addition of a third type increases the *number* of errors, but this does not necessarily result in higher *rates* of error. In fact, for the lower levels of site duration variability, the error rate is actually slightly reduced! In the long run, however, it may be more significant that the addition of a third type resulted in a change in slope of the central production curve, and that this is probably the cause of the additional errors (see below). If this is true then, as the number of contemporaneous types is increased, one would expect more errors. It is not yet clear under what conditions this would or would not result in higher rates of error. Model 4 does not test the full range of possibilities presented by multiple contemporaneous types, and further study is needed before any definite conclusions can be reached.

4. *A Leveling Off in Production During a Type's Rise or Decline*

It is clear from Table 1 (see Model 5A(1) in Part IV; Model 5B(1) in Part V) that a leveling off in production in the presence of variable occupation span can result in seriation errors which would not have occurred if site durations were equal. The results for Model 5B(1) further suggest that the number of errors will increase if the leveling off period is lengthened. It should be noted, however, that the number of errors will quickly reach a peak and then taper off. (It was not informative to calculate error rates for Models 5A, 5B, and 6 because such rates would be dependent, in part, on the slope of the curves; nevertheless, the trends indicated by the actual number of errors are not misleading.)

5. *Small-Scale Reversals in Pottery Type Production Levels*

As in the previous case, the interaction between a small-scale reversal in production and variable occupation span can result in seriation errors that would not have occurred if site durations were equal (see Part VI of Table 1). It is also clear, however, that these errors only occur when the interval between site median occupation dates is relatively small (see below).

6. *Changes in the Interval Between Site Median Occupation Dates*

Here, the results are generally what one might expect. When the interval is reduced, serious levels of error occur. For example, in Table 1, compare Model 3A(1) with Model 3A(3) in Part II; or, compare Model 5A(1) with Model 5A(2) in Part IV (although here the length of the basal units was also increased). Conversely, when the interval is increased, error levels drop dramatically. For example, compare Model 3A(1) with Model 3A(4) in Part II; or, compare Model 5A(1) with Models 5A(3 and 4) in Part IV (although, here again, the basal units were increased in length).

Finally, it is worth noting that, although an increase in the interval from t to $2t$ for Model 3A eliminated most errors (compare 3A(1) with 3A(4)), unit (site) occupation spans still *overlapped to a considerable degree*, e.g., when the magnitude of site duration variability was four, there was a 50% overlap. Thus, variable occupation span does not necessarily lead to errors in the presence of extensive overlapping in site occupation span.

7. *Changes in the Occupation Lengths of All Sites Relative to the Overall Life Span of a Given Pottery Type*

If the interval between median occupation dates is held constant and the size of the basal units is allowed to expand (which automatically lengthens the longer units), the error rate rises dramatically (compare Model 3A in Part I with Model 3A(3) in Part II). In fact, it more than doubles at high levels of site duration variability.

The above results have important archaeological implications. For example, suppose that seriations are to be performed in two different areas and that the pottery type life spans, the average interval between median occupation dates, and the magnitude of site duration variability are about the same in both cases. Suppose further, however, that the shorter occupation spans (i.e., basal units) in the first area are approximately of length x, whereas, in the second area they are about $2x$. Based on the results above, the seriation in the first area will produce a lower level of error. Put another way, if parameter values were about the same for both seriations, except that pottery life spans were approximately of length y in one, and $2y$ in the other, rates of error would be lower in the latter case. In fact, results from Table 1 suggest that for a set of sites of a given magnitude of variable occupation span, the longer pottery type life spans are relative to site occupation spans, the less the potential for error.

8. *Changes in Both Interval and Length*

Depending on the models involved, two different pictures emerge:

1. *Models which include the period of maximum production of its types* (such as Model 3A). When the size of adjacent basal units is increased from *t* to *2t* to *4t*, the interval between site median occupation dates increases from *t/2* to *t* to *2t*, and *yet the error rate worsens* (compare Model 3A in Part I with Models 3A(1 and 2) in Part II). This demonstrates that the interval between median occupation dates is not the only factor which determines whether errors will or will not occur. The length of site occupation spans relative to pottery type life spans is also an important factor.

2. *Models which do not include the period of maximum production of its types* (Models 5A, 5B, and 6). Here the situation is not the same as that described above. If both the interval between site median occupation dates and the length of all site occupations are increased, most of the errors disappear. Compare Model 5A(1) with Models 5A(3 and 4) in Part IV; Model 5B(1) with 5B(2) in Part V; and the Model 6(1) with Model 6(2) in Part VI of Table 1.

In addition to all the seriations analyzed above, two extreme cases were examined whose results are not given in Table 1:

1. Using Model 2, the magnitude of site duration variability was allowed to vary from two to ten, but *site occupation spans were not permitted to overlap* (i.e., all were adjacent). *No errors were produced* by these seriations.

2. Again using Model 2, a single seriation was performed utilizing an unbroken succession of five pottery types. Basal units (sites) contained two to three types and the longer units four to five types, and two of the types present in the longer units were totally absent from all basal units. This seriation produced *two separate orders*, a basal unit order and a longer unit order, *linked end to end!*

SUMMARY OF RESULTS

The preceding discussion can now be summarized in the form of conclusions about the precise nature of the effects of variable site occupation span on the results of frequency seriation.

1. Variable site occupation span may create erroneous chronological placements within a seriated order whenever there is *change in the rate of ceramic change*, i.e., change in the slope of a pottery type production curve. However, if no change in slope occurs, no errors occur. For example, one could seriate, without errors, any set of sites whose occupation spans fell entirely within the time period shown in Figure 14. These statements are based on the fact that all errors shown in Table 1 occur in the vicinity of changes in slope. As the magnitude of site duration variability increases, errors occur in increasing numbers and spread out from these areas of change in slope.

2. The most serious errors occur during the transition period between the rise and decline in a type's production, and brief transition periods are particularly devastating. Small-scale reversals or a leveling off in production may also result in errors.

3. The frequency of errors is directly proportional to the rate of pottery type replacement.

4. The frequency of errors is inversely proportional to the size of the interval between site median occupation dates.

5. The length of pottery type life spans *relative* to site occupation spans is an important determinant of the rate of error generated by a given level of site duration variability. More specifically, this means that for a set of sites with a given magnitude of variable occupation span, the longer pottery type life spans are—relative to site occupation spans—the less the potential for error.

6. Given a change in slope of a type's production curve, statement 4 above cannot be seen as the prime determinant of the error rate produced by variable occupation span. Statement 5 is also critical.

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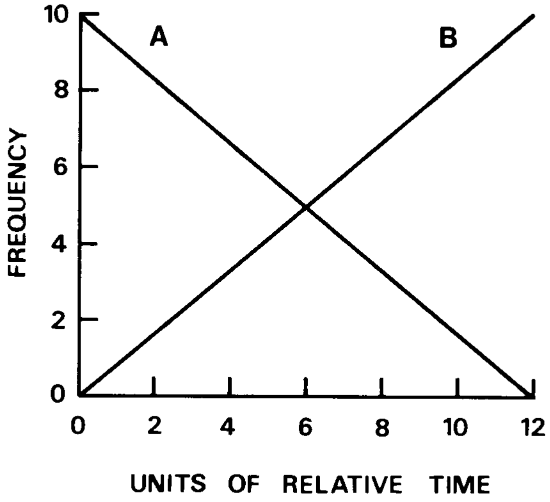

Figure 14. Period of ceramic type replacement without change in slope. It would be possible to seriate, without errors, any set of sites whose occupation spans fell entirely within the time period shown.

7. Considerable overlap in site occupation spans of variable length does not necessarily produce seriation errors. However, if there is no overlap, no errors occur.

8. Increased numbers of contemporaneously produced types do not necessarily mean higher error rates. In some instances, they may even produce a slightly lower rate. Until their effects are more clearly understood, they should be assessed on a case-by-case basis.

9. Variable occupation span need not be ceramically obvious for errors to occur. For most seriations in this study, most longer units had the same number of pottery types as the basal units, yet errors were common. Furthermore, it can be shown that sites with different numbers of types may or may not be of comparable duration.

10. It is impossible to detect the negative effects of variable site duration solely by studying the relative frequencies of types in the context of a Ford graphic seriation because errors may be present without any violation of the unimodal curve model. In fact, this situation was common for all models except Models 1 and 2.

One final point. On the basis of the results in Table 1, the reader may be tempted to conclude that errors will be infrequent if the magnitude of variable site duration is two or less. However, if additional seriations were run using basal units of even longer duration (see earlier discussion and statements 4 through 6 above), errors would begin to appear even at these low magnitudes of variability.

Variable Site Occupation Span and Variable Pot Life Span

Earlier it was stated that the interaction between these two variables is not a serious source of error. This will now be demonstrated.

David (1972) and DeBoer (1974) have shown that variable pot life span and variable site occupation span interact to produce changes in the relative frequencies of pot types of different function found on sites regardless of whether any changes ever occurred in their relative frequency of use. At first glance, this would appear to have serious consequences for seriation. McNutt (1973) has shown, however, that frequency seriations should not be based on types of different function, and that attempts to do so can have disastrous results whether pots have different life spans or not. Consequently, if one is willing to grant to the archaeologist the ability to make at least gross functional distinctions on morphological, stylistic, and ethnographic grounds, the extent of the problem is greatly reduced. If one does not believe such distinctions are feasible, it can still be shown that variable pot life-span-occupation-span interaction has only minimal effects.

Both David and DeBoer compare the relative frequencies of pot types of different function from the ethnographic record with those same frequencies projected into the archaeological record after 100 years of deposition. David (1972:142) points to the substantial differences between the two data sets and concludes that seriation may be in trouble. On the other hand, DeBoer (1974: 377, Table 1) shows that, at least for his data, the differences between the relative frequencies of pot types after 5 and 100 years are minimal, and thus seriations would not be seriously affected unless sites were occupied for less than 5 years.

DeBoer uses David's (1972:142) formula for calculating the projection of type frequencies, except that David assumes all usable pots would be left at a site when abandoned, whereas DeBoer (1974:Table 1) assumes all would be removed. Neither extreme is very satisfactory. It is more likely that something approaching one-half of the usable pots would be left behind, and both author's figures were recalculated accordingly.

These figures show that for DeBoer's data the mean difference in the relative frequencies of the various pot types between the 10- and 100-year-old archaeological records would be 0.34%, with a range of 0.0% to 1.4%. For David's data (whose pots have considerably longer life spans, similar to Foster's [1960]), the mean difference after 10 years would be 1.4%, with a range of 0.2% to 2.7%; after 20 years, it would only be 0.72%, with a range of 0.1% to 1.3%. Clearly then, the interaction between variable pot life span and site occupation span would only be a significant source of error for seriations including both sites of very short occupation span and pot types of different function with substantially different life spans. This is not likely to occur very often.

IMPLICATIONS FOR SERIATION AND PROSPECTS FOR A SOLUTION

Although variable pot life span is not an important factor, the analysis of the seriation results shown in Table 1 makes it clear that variable site occupation span is probably a more important source of error than previously thought. What are the prospects for a solution?

Dunnell's and Cowgill's Approaches Reexamined

Dunnell (1970) proposes removing those units which are substantially at variance with the unimodal curve model in the context of a Ford graphic seriation (see Figure 1). Only those units which create moderate distortion at the ends of distributions would be tolerated. In the light of this study, how effective would his solution be? First of all, it would eliminate the serious distortion caused by extreme cases where the sites of relatively long duration have some pottery types that are totally absent from the sites of relatively short duration. It would also eliminate most of the errors associated with Model 1. On the other hand, it would not eliminate the errors associated with Model 2 and most of the other models. In fact, most would be impossible to detect! Furthermore, even in those cases where there exist important reversals within distributions, it still remains that one cannot be certain whether variable occupation span or some other source of error, such as sampling error, is the culprit (Marquardt 1978:297–298). In short, while Dunnell's approach is a step in the right direction, it is insufficient in practice.

As shown above, the main difficulty with Dunnell's solution is that many errors may go undetected. Interestingly enough, Dunnell himself proposes a solution to the problem of undetectable errors, but it is in the context of spatial variability (Dunnell 1970:316). He suggests performing multiple seriations on the same set of sites using different artifact classes, e.g., projectile-point types, pottery types, house types, burial types, etc. Sites which are not ordered in the same way in all seriations must then either be regarded as contemporary (i.e., not capable of being chronologically distinguished) or be removed altogether. In most situations, however, it is unlikely that several classes of artifacts, each present in sufficient numbers and possessed with sufficient variability for adequate seriation, will be available (Marquardt 1978:298). Moreover, unless all artifact classes are capable of approximately the same degree of temporal discrimination, it would not be very useful to compare seriated orders. Thus, this author would have to agree with Marquardt (1978:299) that performing multiple seriations is a solution, but generally an impractical one.

Cowgill (1972) states that any two sites whose occupation spans overlap to any serious degree are likely to be seriated in reverse order due to the presence of site duration variability and/or other sources of error, such as sampling error. The present study has shown, however, that even extensive overlapping of site occupation spans does not necessarily produce errors—at least not in the context of variable occupation span alone. This is especially true for sites whose median occupation dates are nowhere near important changes in the slope of a pottery type's production curve (see Figure 14). While it is true that errors do not occur if there is no overlap in occupation spans, most seriations do contain sites with overlapping site occupations, especially those related to studies of evolving settlement patterns. However, it is still probably true that if two or more sites are contemporaneous for much of their occupation spans, the combined effects of site duration variability, sampling error, and spatial variability are likely to result in reversals in site order.

Alternative Approaches

In the American Southwest (and elsewhere) many pottery types have relatively short life spans and relatively rapid replacement rates. This has been achieved by delineating types based on changes in one or two attribute dimensions, such as design or rim form (e.g., the Rio Grande Glazewares; see Mera [1933]). While such types may be useful as index fossils, it is legitimate to question whether they are the best for seriation. The present study has shown that relatively few errors will be produced due to variable occupation span if seriations are based on types with relatively slow replacement rates and whose life spans are relatively long when compared to site occupation spans. If this be the case, then why not create types which fulfill these conditions, thereby reducing errors to a minimum? Unfortunately, it is not as simple as that.

While the use of relatively long-lived types with slow replacement rates would reduce rates of error, an important price would often be paid—namely, a reduction in the degree of temporal resolution that the seriation can provide. It is already the case in certain areas of the Southwest that many sites cannot be included in a typological seriation because they contain only one type in a given painted or utility ware series. Were types with longer life spans to be used this problem would be aggravated. Nevertheless, in those situations where relatively long-lived types could be used without a substantial loss in temporal resolution, such a procedure can be viewed as a satisfactory solution.

What other approaches are possible? In addition to trying to limit the number of errors, one can try to estimate the level of error for a given seriation. For example, regardless of one's knowledge of site duration variability for a given set of sites, if types have slow replacement rates and appear to have relatively long life spans when compared to the typical site occupation span, and if it is suspected that the intervals between site median occupation dates are relatively large, then few seriation errors will occur.

An example may help to clarify this. If one unit of relative time, t, is set equal to one decade, most of the models in this study fall within the range of typical pottery production curves found in the American Southwest (see references cited above in discussion of the models). For example, Model 1 would have a life span of 100 years, Models 2 and 3B a life span of 120 years, Model 3A, 180 years, and so on (see Figures 3-6). Most of the models would also fit with regard to the rapidity of type replacement (see the same references). For example, Models 3A and 3B would have type replacement periods of 50 and 20 years, respectively. Note, too, that for this study the interval between site median occupation dates was generally $t/2$ or t (see Table 1), or 5–10 years in the present example. Thus, if for a given seriation most type replacement periods are relatively long (e.g., 75–100 years; see results for Models 3A and 3C in Table 1), and if type life spans are relatively long when compared to the typical site occupation span (see Model 3A, where the type life span is 180 years and occupation spans range from 10–60 years), and if site median intervals are relatively large (e.g., 30–40 years; see Model 3A(4), Part II, Table 1, where the interval is 20 years), then few seriation errors will occur.

On the other hand, if type replacement is rapid (e.g., 20 years; see Model 3B), and if type life spans are similar to or shorter in length than the typical site occupation span (see Model 3A(2), where the type life span is 180 years and occupation spans range from 40–160 years), and if site median intervals are thought to be small (e.g., 5–10 years), then seriation errors are likely to be quite serious. In fact, they may be so serious that it would be more appropriate and more meaningful to perform a cluster analysis based on the type frequencies at each site and then seriate the site clusters (see Read [1979]).

If the archaeological context does not fit into one of the two categories discussed above, then it might be useful to construct a graphic model like the ones in this study (Read 1978, personal communication). The model could be based on the approximate beginning and ending dates for the production of the pottery types found on the sites. The only difference would be that in order to construct the unimodal curves, it would first be necessary to label the y-axis in percentage units and the x-axis in actual years. Once the idealized curves (symmetrical and streamlined as in this paper) had been constructed and their slopes determined, the model could be converted to one labeled in relative time units and arbitrary units of artifact frequency. The resulting configuration could then be compared with the models and conclusions of this paper. Finally, if desired, seriations could be run to estimate the actual level of error. Such seriations would involve the probable range in occupation spans present in the real data and an educated guess as to the average interval between site median occupation dates.

Attribute Seriation, Especially Microseriation

The question still remains whether there exists a viable solution that would eliminate most of the errors due to variable site occupation span. Until now the discussion has been centered upon *pottery type* seriation. The situation is somewhat more interesting if one turns to *attribute* seriation (see Rouse [1939]; Menzel et al. [1964]; Marquardt [1974, 1979]; LeBlanc [1975]; and Drennan [1976]). Although attribute seriation is not logically different from type seriation, i.e., the production curves in Models 1–6 could also be treated as attribute production curves, there are nevertheless some important differences in the context of this analysis.

First of all, many attribute seriations—in particular, those based on the evolution of attribute frequencies or values within the context of one or two types—deal with sites, site components, or excavation units that have relatively short occupation or deposition spans. If occupation spans are short, the magnitude of site duration variability is likely to be relatively small, which in turn means relatively low rates of error. In this sense, then, Ford was right when he originally suggested that seriations should be done with sites of *short* duration, because they produce more refined chronologies.

Second, when performing such attribute seriations, or microseriations as LeBlanc (1975) calls them, it is generally possible to use R-mode components factor analysis to select the most time-sensitive variables (see Marquardt [1974, 1979]; and LeBlanc [1975]). Marquardt has clearly shown that such a technique not only selects time-sensitive attributes but also selects only those which either generally increase or decrease in frequency (nominal variables) or value (continuous variables) throughout the time period of the seriation, but not both. This means that any attributes with unimodal (or bimodal) production curves will not be chosen (Marquardt 1974:104–106). This is important because *a major source of error, i.e., the transition period between the rise and decline of a pottery type (or attribute), will generally be absent from the seriation.* (The elimination of bimodal distributions is also relevant to McNutt's [1973] criticism of seriation.)

At this point the reader may argue that the variables used in the R-mode factor analytic approach are not part of a closed relative frequency system, i.e., the variable values are not interdependent. While this is correct, it is nonetheless true that for any given variable a seriation based on that variable will be subject to the same kind of errors that variable occupation span causes in a closed frequency system. (See LeBlanc [1975] for scalings based on a single attribute.)

Finally, it should be noted that the benefits gained by using the factor analytic procedure may be partially offset by the increased likelihood of small-scale reversals in attribute production. Nevertheless, it is reasonably safe to state that attribute microseriations will generally be freer of errors due to variable site occupation span than will typological seriations.

Concluding Remarks

To conclude, it has been demonstrated how, and under what circumstances, variable site occupation span affects frequency seriation results, and further, that its effects pose a more serious problem for the reliability of such seriations than once thought. It has been established that past attempts to deal with the problem are insufficient for the task. It has been shown that for many seriations, especially typological ones, the problem cannot be easily resolved; however, it is possible to estimate the magnitude of the errors produced. Finally, it has been shown that for microseriations the effects of variable site occupation span are generally less serious, and that something approaching a solution is possible.

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REFERENCES CITED

Binford, Lewis R.
1973 Interassemblage variability—the Mousterian and the 'functional argument.' In *Explanation of culture change: models in prehistory*, edited by C. Renfrew, pp. 227–254. Academic Press, New York.
Breternitz, David A.
1966 An appraisal of tree-ring dated pottery types in the Southwest. *Anthropological Papers of the University of Arizona* 10. University of Arizona Press, Tucson.
Colton, Harold S.
1953 Potsherds. *Museum of Northern Arizona, Bulletin* 25. Flagstaff.
Cowgill, George L.
1968a Archaeological applications of factor, cluster, and proximity analysis. *American Antiquity* 33: 367–375.
1968b Review of Computer analysis of chronological seriation, by F. Hole and M. Shaw. *American Antiquity* 33:517–519.
1970 Some sampling and reliability problems in archaeology. In *Archéologie et calculateurs*, edited by J. C. Gardin, pp. 161–172. Editions du Centre National de la Recherche Scientifique, Paris.
1972 Models, methods and techniques for seriation. In *Models in archaeology*, edited by D. L. Clarke, pp. 381–424. Methuen, London.
David, Nicholas
1972 On the life span of pottery, type frequencies, and archaeological inference. *American Antiquity* 37:141–142.
DeBoer, Warren R.
1974 Ceramic longevity and archaeological interpretation: an example from the Upper Ucayali, Peru. *American Antiquity* 39:335–343.
Deetz, James, and Edwin Dethlefsen
1965 The Doppler effect and archaeology: a consideration of the spatial aspects of seriation. *Southwestern Journal of Anthropology* 21:196–206.
Drennan, Robert D.
1976 A refinement of chronological seriation using nonmetric multidimensional scaling. *American Antiquity* 41:290–302.
Dunnell, Robert C.
1970 Seriation method and its evaluation. *American Antiquity* 35:305–319.
1971 *Systematics in prehistory*. Free Press, New York.

Fish, Paul R.
1978 Consistency in archaeological measurement and classification: a pilot study. *American Antiquity* 43:86–89.

Ford, James A.
1962 A quantitative method for deriving cultural chronology. *Pan American Union, Technical Manual* 1. Washington, D.C.

Foster, George M.
1960 Life-expectancy of utilitarian pottery in Tzintzuntzan, Michoacán, Mexico. *American Antiquity* 25:606–609.

Gelfand, Alan E.
1971 Seriation methods for archaeological materials. *American Antiquity* 36:263–274.

Hole, Frank R., and Mary Shaw
1967 Computer analysis of chronological seriation. *Rice University Studies* 53(3). Houston.

Johnson, Alfred E., and Ann S. Johnson
1975 K-means and temporal variability in Kansas City Hopewell ceramics. *American Antiquity* 40: 283–295.

Johnson, Leroy, Jr.
1972 Introduction to imaginary models for archaeological scaling and clustering. In *Models in archaeology*, edited by D. L. Clarke, pp. 309–379. Methuen, London.

Kroeber, Alfred L.
1916 Zuñi potsherds. *Anthropological Papers of the American Museum of Natural History* 18(1):7–37. New York.

LeBlanc, Steven A.
1975 Micro-seriation: a method for fine chronologic differentiation. *American Antiquity* 40:22–38.

Marquardt, William H.
1974 *A temporal perspective on late prehistoric societies in the eastern Cibola area: factor analytic approaches to short-term chronological investigation.* Ph.D. dissertation, Washington University. University Microfilms, Ann Arbor.
1978 Advances in archaeological seriation. In *Advances in archaeological method and theory* 1, edited by M. B. Schiffer, pp. 257–314. Academic Press, New York.
1979 A factor analytic approach to seriation. *Plains Anthropologist* 24(86):309–328.

Matson, R. G., and William D. Lipe
1977 Seriation of Pueblo ceramic assemblages from Cedar Mesa, SE Utah. Ms. available from the authors at the University of British Columbia and Washington State University, respectively.

McNutt, Charles H.
1973 On the methodological validity of frequency seriation. *American Antiquity* 38:45–60.

Meighan, Clement W.
1959 A new method for the seriation of archaeological collections. *American Antiquity* 25:203–211.

Menzel, Dorothy, John H. Rowe, and Lawrence E. Dawson
1964 The Paracas pottery of Ica: a study in style and time. *University of California Publications in American Archaeology and Ethnology* 50. Berkeley.

Mera, H. P.
1933 A proposed revision of the Rio Grande glaze paint sequence. *Laboratory of Anthropology, Technical Series Bulletin* 5. Santa Fe.
1935 Ceramic clues to the prehistory of north central New Mexico. *Laboratory of Anthropology, Technical Series Bulletin* 8. Santa Fe.

Phillips, Philip, James A. Ford, and James B. Griffin
1951 Archaeological survey in the lower Mississippi alluvial valley, 1940–1947. *Papers of the Peabody Museum of American Archaeology and Ethnology* 25. Harvard University, Cambridge, Mass.

Plog, Fred
1976 Ceramic analysis. In Chevelon Archaeological Research Project 1971–72, edited by F. Plog, J. N. Hill, and D. W. Read. *U.C.L.A. Archaeological Survey Monograph* 2:44–59.

Read, Dwight W.
1974a Some comments on typologies in archaeology and an outline of a methodology. *American Antiquity* 39:216–242.
1974b Some comments on the use of mathematical models in anthropology. *American Antiquity* 39:3–15.
1979 The effective use of radiocarbon dates in the seriation of archaeological sites. In *Radiocarbon dating*, edited by R. Berger and H. E. Suess, pp. 89–94. University of California Press, Los Angeles.

Renfrew, Colin, and Eugene Sterud
1969 Close-proximity analysis: a rapid method for the ordering of archaeological materials. *American Antiquity* 34:265–277.

Rouse, Irving B.
1939 Prehistory in Haiti, a study in method. *Yale University Publications in Anthropology* 21. New Haven.

1967 Seriation in archaeology. In *American historical anthropology: essays in honor of Leslie Spier*, edited by C. L. Riley and W. W. Taylor, pp. 153–195. Southern Illinois University Press, Carbondale.

Rowe, John H.

1961 Stratigraphy and seriation. *American Antiquity* 26:324–330.

Schiffer, Michael B.

1975a Arrangement vs. seriation of sites: a new approach for relative temporal relationships. In The Cache River archaeological project: an experiment in contract archaeology, assembled by M. B. Schiffer and J. H. House. *Arkansas Archaeological Survey, Research Series* 8:257–263.

1975b The effects of occupation span on site content. In The Cache River archaeological project: an experiment in contract archaeology, assembled by M. B. Schiffer and J. H. House. *Arkansas Archaeological Survey. Research Series* 8:265–269.

1976 *Behavioral archaeology*. Academic Press, New York.

South, Stanley

1972 Evolution and horizon as revealed in ceramic analysis in historical archaeology. In *The Conference on Historic Site Archaeology Papers, 1971* 6(2):71–116. The Institute of Archaeology and Anthropology, University of South Carolina, Columbia.

1978 Pattern recognition in historical archaeology. *American Antiquity* 43:223–230.

Spier, Leslie

1917 An outline for a chronology of Zuñi ruins. *Anthropological Papers of the American Museum of Natural History* 18(3). New York.

Stubbs, Stanley A., and W. S. Stallings, Jr.

1953 The excavation of Pindi Pueblo, New Mexico. *Monographs of the School of American Research and the Laboratory of Anthropology* 18. Santa Fe.